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Productivity of Ospreys and Bald Eagles in the Williston And Dinosaur Reservoirs, North-Central British Columbia, 1995

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ABSTRACT

Helicopter surveys were used to identify and record osprey *(Pandion haliaetus)* and bald eagle *(Haliaeetus leucocephalus)* nest sites during March, June, and August 1995 in the Williston Reservoir watershed in north central British Columbia. The perimeter of the Williston Reservoir (~1800 km) was surveyed in order to document occupancy, productivity, and nest site selection of both species of raptors.

Ninety-eight osprey nests and 61 bald eagle nests were identified during the surveys. Eighty-seven of the osprey nests (89%) and 36 of the bald eagle nests (60%) were occupied representing a nesting density of 0.05 occupied osprey nests/km and 0.02 occupied bald eagle nests/km of shoreline. Sixty percent of the occupied osprey nests were located in the Parsnip Reach of the reservoir, while the remaining 40% were located in the Finlay Reach. No occupied osprey nests were found in the Peace Reach. Occupied bald eagle nests were fairly uniformly distributed between the Finlay, Parsnip and Peace Reaches of the Reservoir (42%, 33% and 25%, respectively).

Fifty-five percent (48 of 87) of the occupied osprey nests and 64% (23 of 36) of the occupied bald eagle nests were successful. Osprey productivity for the entire reservoir was estimated to be 1.18 ± 0.13 young/occupied nest, and 2.15 ± 0.10 young/successful nest. Productivity was 1.26 ± 0.22 and 1.13 ± 0.16 young/occupied nest and 2.32 ± 0.17 and 2.03 ± 0.13 young/successful nest in the Finlay and Parsnip Reaches, respectively. The productivity of ospreys in the Manson Arm (within the Parsnip Reach) was 0.96 ± 0.21 young/occupied nest and 2.07 ± 0.21 young/successful nest. Bald eagle productivity for the entire reservoir was 0.86 ± 0.13 young/occupied nest and 1.35 ± 0.10 young/successful nest. Productivity in the Finlay, Parsnip and Peace Reaches ranged from 0.50 to 1.13 young/occupied nest and 1.14 to 1.55 young/successful nest. No significant differences in the productivity of either ospreys or bald eagles was noted between any of the major reaches or arms of the Williston Reservoir.

Occupied osprey nests were predominantly found in dead trees (97%), most of which could not be identified to species. The vast majority of these nests (80%) were in trees located in the flood zone that have remained standing since the reservoir was flooded. Occupied bald eagle nests were located primarily in live deciduous trees (72%). Most of these nests (86%) were located on the slopes above the edge of the Reservoir.

Productivity and densities of ospreys and bald eagles are discussed, and sur y timing and methods are evaluated. How the creation of the Williston Reservoir has potentially changed the distribution and productivity of both ospreys and bald eagles is also discussed.

ACKNOWLEDGMENTS

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INTRODUCTION

Although ospreys *(Pandion haliaetus)* and bald eagles *(Haliaeetus leucocephalus)* can be found throughout British Columbia, their preferred habitat is generally close to water (rivers, lakes, or ocean). Much of the population and productivity data collected on these species in BC to date pertains to coastal or southern interior populations. While it is known that both ospreys and bald eagles nest along the Williston Reservoir, no data on the distribution or productivity of either species were available prior to these surveys.

Almost 30 years have past since the creation of the Williston Reservoir in north-central BC in 1968. Since no data pertaining to osprey and bald eagle populations within the upper Peace River drainage were collected prior to dam construction, the impact of reservoir formation on these populations is unknown and can not be determined. It is suspected however, that changes in the distribution and productivity of ospreys and bald eagles have likely occurred since the reservoir was developed.

In 1995, the Peace/Williston Fish and Wildlife Compensation Program (PWFWCP) embarked on a project to assess osprey and bald eagle breeding populations within the area of the Reservoir. The objectives of the project were to first determine the population status, nest habitat use, and nesting distributions of bald eagles and ospreys along the perimeters of the Williston and Dinosaur Reservoirs, and secondly, to undertake measures to protect and/or enhance habitat and population numbers if and where necessary.

The objectives of this report are to present and analyze data collected during 3 osprey/bald eagle aerial surveys conducted in 1995, compare productivity and density data to those available in the literature, and make recommendations for further inventory and research. Specific objectives of the 3 flights conducted in 1995 were to: 1) identify and record existing raptor nest locations; 2) determine the number and species of breeding pairs occupying nest sites; and 3) determine the number of fledglings per occupied nesting site. These data will also provide the basis for planning the timing of additional productivity surveys in the Williston Reservoir. A more detailed assessment of the survey methodology used for the nest identification flight was prepared under a separate title for the Resource Inventory Committee (RIC), Ministry Of Environment, Lands & Parks, Victoria BC (Zemlak *et al.* 1995).

STUDY AREA

The study area encompasses the Williston and Dinosaur Reservoirs in north-central British Columbia (Figure 1). In 1967, the W.A.C. Bennett Dam was constructed on the Peace River, impounding the upper Peace River and the lower sections of the Finlay and Parsnip Rivers to form the Williston Reservoir, B.C.'s largest body of fresh water. The reservoir has a surface area of 1,778 km^2, and a shoreline perimeter of 1,770 km (BC Hydro 1988). Several major river systems flow into the Reservoir, draining an area of 69,930 km^2 (BC Hydro 1991). The completion of the Peace Canyon Dam in 1980, 23 km downstream of the W.A.C.

Bennett Dam, created the smaller Dinosaur Reservoir which has a surface area of 8 km") and a shoreline perimeter of 54 km (BC Hydro 1987).

The majority of the study area lies within the Sub-Boreal Interior Ecoprovince with two exceptions: the northern tip of the Finlay Reach which lies in the Boreal Mountains Ecoprovince, and the eastern end of the Dinosaur Reservoir which lies in the Boreal Plains Ecoprovince. The Williston Reservoir is surrounded by the Sub-Boreal Spruce (SBS) biogeoclimatic zone, which includes the moist cool (mk1 and mk2) and wet cool (wk2) variants. The Boreal White and Black Spruce (BWBS) biogeoclimatic zone occurs at the northern tip of the Finlay Reach (dry cool variant [dk1]), and along the eastern half of the Peace Arm including the Dinosaur Reservoir (moist warm variant [mw1]).

The major tree species found along the perimeter of both reservoirs are white spruce *(Picea glauca),* lodgepole pine *(Pinus contorta),* and trembling aspen *(Populus tremuloides),* with smaller pockets of black cottonwood *(Populus trichocarpa)* and paper birch *(Betula paperifera).* Since much of the landbase under the Williston Reservoir was not logged prior to flooding, standing snags are found along sections of this reservoir's shoreline, and are common in many of its shallow bays. The topography adjacent to the Finlay and Parsnip Reaches of Williston Reservoir is gently to moderately sloping, with some cutbanks. The Peace Reach is the deepest part of Williston Reservoir, with many sections of the shoreline dominated by steep rock cliffs. The shoreline of Dinosaur Reservoir has moderate to steep forested slopes.

The level of Williston Reservoir fluctuates seasonally due to the amount of inflow, and the demand for hydroelectric power generation. In winter, the demand for electricity is high while inflow from the tributaries is low, and the Reservoir typically reaches its lowest level in April. The Reservoir rises throughout the summer, as snowmelt increases the amount of inflow to the reservoir and the demand for power is low, to reach it's highest level in August. The Reservoir level fluctuates between the normal minimum elevation of 642 m, and full pool at 672 m. The Finlay and Parsnip Reaches of Williston Reservoir usually freeze over by December, while the deeper Peace Reach freezes by early January. Ice breakup typically occurs in the first week of May. The first few kilometres of the Dinosaur Reservoir downstream of the W.A.C. Bennett Dam remain ice-free throughout the year, while the remainder freezes over by January. It is normally ice-free by April.

Human development around the Reservoirs is minimal and includes the small towns of Mackenzie (at the south end of the Parsnip Reach) and Hudson's Hope (near the Peace Canyon dam). In addition, the First Nation community of Tsay Keh is situated at the north end of the Finlay Reach, and a few small logging camps occur throughout the watershed. Forest harvesting is the primary industrial activity in the watershed, with the Reservoir used as a transportation corridor for timber. The Reservoir receives low to moderate use by recreationalists, primarily for boating and fishing.

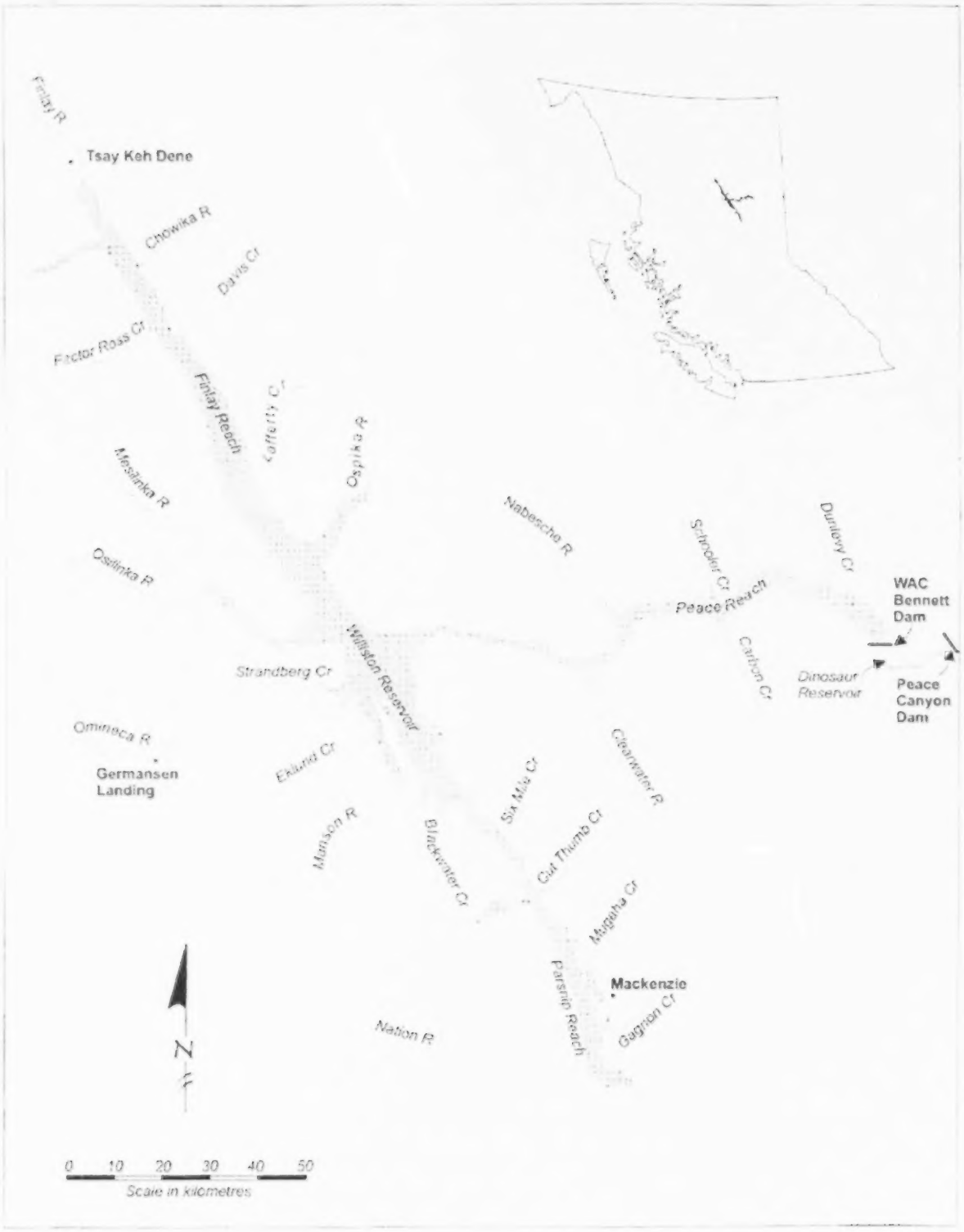

Figure 1. Study area for the 1995 Williston Reservoir osprey and bald eagle surveys.

There are many fish species present in the Reservoir and its tributaries that may be potential prey for osprey and bald eagles. Spring-spawning species include rainbow trout *(Oncorhynchu s mykiss),* Arctic grayling *(Thymallus arcticus),* lake chub *(Couesius plumbeus),* peamouth chub *(Mylocheilus caurinus),* northern squawfish *(Pyychocheilus oregonensis),* longnose dace *(Rhinichthys cataractae),* redside shiner *(Richardsonius balteatus),* suckers *(Catostomus sp.),* and sculpins *(Cottus sp.)* (McPhail and Carveth 1993). Fall spawning species include kokanee *(Oncorhynchus nerka),* bull trout *(Salvelinus confluentus),* lake whitefish *(Coregonus clupeaformis),* and whitefish species *(Prosopium sp.).* Since ospreys and bald eagles cannot dive to great depths to capture prey, other fish species in the reservoir such as burbot *(Lota lota)* and lake trout *(Salvelinus namaycush)* that typically reside in deep waters are less likely taken as prey.

METHODS

Survey Methods

A three person crew conducted aerial surveys in March, June and August 1995 using a Bell 206 Jet Ranger helicopter. Surveys were conducted according to basic RIC standards (RIC 1997). All surveys commenced about two hours after sunrise and ended one hour before dark. The person in the front seat of the helicopter was responsible for navigating, searching for nest sites, counting eggs, fledglings and adults, and recording "map" coordinates of each nest site. The two rear seat observers searched for nest sites and counted eggs, fledglings and adults. One rear seat observer also recorded the data collected, while the other photographed nest sites.

Survey 1 was conducted between February 28 and March 2, 1995. The entire perimeters of Williston and Dinosaur Reservoirs were flown to document the location of all osprey and bald eagle nest sites. The survey was conducted between 50-80 m above the ground at speeds ranging from 130-160 km/hr depending on the shoreline habitat. The helicopter flew along the edge of the treeline so that observers could search for nests on snags in the reservoir, and for nests on trees up to 300 metres inland. When a nest site was located, the following data were recorded: the location of the nest in relation to the Reservoir (shoreline or upslope), tree species nest was located in, and the number of adjacent snags. Latitude and longitude for each nest site were recorded using the Global Positioning System (GPS) unit in the helicopter (NAD83 datum), and a photograph was taken of each nest. The nest search survey was conducted in late winter when the nests were filled with snow, and the deciduous trees lacked their leaves, making the nests more visible than in summer. Detailed survey methods for Survey 1 are presented in Zemlak *et al.* (1995). The 1,800 km of Reservoir shoreline took 15.5 hours of helicopter time to survey. The level of the Williston Reservoir at the time of the survey was 660.3 m.

The main objective of Survey 2 was to revisit all nest sites located on the first survey, and document nest occupancy and clutch size. New nest sites were also documented. Survey 2 was conducted on June 1

and 2, 1995, and took 13.2 hours of helicopter time to complete. Each nest site was located by its previously recorded latitude and longitude using the helicopter's GPS unit. Data collected at each nest site included the species using the nest, the number and behaviour of adults present, and the number of eggs or chicks in the nest. The level of Williston Reservoir on June 1 was 664.4 m, 4.1m higher than the level in early March.

Survey 3 was conducted on August 1 and 2, 1995, taking 14.3 hours of flying time to complete. This survey involved revisiting all previously documented nest sites to determine number of fledglings and document any new nest sites. The number of fledglings in each nest, and the number and behaviour of adults in the vicinity were recorded. The level of the Williston Reservoir on August 1 was 669.8 m, 9.5 and 5.4 m higher than the levels in March and June, respectively.

Nest site locations were entered into an Excel data base after each survey flight. Maps of the nest sites located on the first survey were generated using QuickMap Computer Mapping System. These maps were used during the second and third helicopter surveys. Final 1:250,000 maps were produced using QuickMap upon completion of the surveys and data entry.

Data Summary and Analyses

Nesting Terminology

Terminology regarding nest status follows that of Postupalsky (1974). An 'occupied' nest was one that was attended by 2 birds early in the season. An 'active' nest was a nest with visible eggs, nestlings and/or fledglings at some time during the aerial surveys, or a nest with an incubating adult in it. These nests may not have had any eggs visible during any of the surveys, but it was assumed that if an adult was observed to be incubating, then eggs were present in that nest at that time. A 'successful' nest is a nest in which at least 1 young was observed nearing or beyond fledging sometime during surveys. Unoccupied nest sites were identified as either a bald eagle or osprey nest. Designation of nest sites were determined through examination of photographs of nest sites that were taken from a helicopter. Large nests in the crotches of trees that had part of the canopy extending above the nest were assumed to be bald eagle nests. Any nests that were located on the very top of a snag were assumed to be osprey nests. Numerous nests were not allocated to either species as they were not easily identified as an eagle or an osprey nest. Unoccupied nests were then combined with the occupied nests and used to describe nest tree and nest site characteristics.

Nesting Density

The number of occupied nests within the study area was divided by the approximate length of shoreline (~1800 km; Zemlak *et al.* 1995) to yield an estimate of the number of occupied nests per km of shoreline in the study area. The number of occupied nest sites for both bald eagles and ospreys were summarized by the three main reaches of Williston Reservoir: Finlay, Parsnip and Peace. The Peace Reach includes Dinosaur Reservoir and the section of the Peace River between the WAC Bennett and Peace Canyon

Dams. The number of occupied nests were also summarized by 'arms' of the reservoir. Arms in this context referred to the inundated bays at the mouths of the Finlay, Parsnip, Omineca, Ospika, and Manson Rivers, and the Dinosaur Reservoir.

Nearest neighbour distances were calculated using GIS for intraspecific nesting distances (occupied nests only). Average intraspecific nearest neighbour distances were calculated. Nearest neighbour distances were calculated only for nest sites surveyed and do not include potentially occupied nest sites in excess of 300 m from the shoreline. Inclusion of these, as yet unsurveyed nest sites, may change average intraspecific nearest neighbour distance for both species.

Nest Site Productivity

The fledgling success of many of the occupied nest sites of both bald eagles and ospreys was not determined, thus, the only reliable estimate of productivity that was determined was the number of young/successful nest. Because the number of young/successful nest is considered a biased estimator of productivity (Steenhof 1987), we also calculated the number of young/occupied nest with the assumption that the nest sites where no fledgling data were available actually represented nest failures. We felt justified in including these nest sites as nest failures because they fell within the range of nest failures reported in other bald eagle and osprey studies. These estimates represent the "worst possible" productivity for the nest sites analyzed. In some cases, especially with respect to eagles, the lack of fledgling data for some nests may have been a result of young having already left the nest.

Productivity of both osprey and bald eagle nests were recorded for the overall study area, and by reach and arm. For ospreys, a t-test was used to examine the differences in the number of young per occupied nests in the Finlay and Parsnip reaches because no nest sites were located in the Peace Reach. Because of the large number of nests in Manson Arm, nesting data from this area were separated from the rest of the data of the Parsnip Reach. A one-way ANOVA was then used to test for differences in the number of young/occupied nest and young/successful nest in the Finlay Reach, Manson Arm, and the Parsnip Reach less the data from Manson Arm. For eagles, one-way ANOVA was used to test for differences in the number of young/occupied nest and young/successful nest in the three reaches of the Williston Reservoir Study Area (WRSA).

Nest Site Selection

The number of occupied and unoccupied bald eagle and osprey nests were summarized by tree status (live or dead) and by tree species. Locations of both occupied and unoccupied bald eagle and osprey nests were classified by their position relative to the shoreline. Shoreline nests were those nests found in inundated snags of the Reservoir. Upslope nest sites were those nests that were located in trees on the slopes above the shoreline of the Reservoir.

RESULTS

Ospreys

Nest Site Density and Distribution

During the 1995 surveys, 98 nest sites in the WRSA were identified as osprey nests. Of these 98 nests, 87 (88%) were considered occupied and active. Forty-eight of the occupied nests (55%) were successful. The remaining 39 nests (45%) had either failed, had already fledged young, or the number of young could not be determined by the time of the third aerial survey.

The overall density of occupied osprey nests was equivalent to 0.05 occupied nests per km of shoreline or 1 nest per 20 km of shoreline. The distribution of occupied osprey nests was not uniform along the entire reservoir shoreline. Sixty percent of the nests were located within the Parsnip Reach, while the remaining 40% were located within the Finlay Reach. No occupied osprey nests were located within the Peace Reach of the Reservoir (Table 1). Manson Arm, an extension of the Parsnip Reach, contained 37% of the total number of occupied nests in the WRSA. Average intraspecific nearest neighbour distances for occupied nest sites were 2.3 km (± 0.5 km; range 0.05-13.3 km). There were a number of locations in the study area where active osprey nests were grouped close together. For the purpose of this study we referred to any group of three or more nests within 500 m from each other as a nesting colony. Manson Arm contained three of the largest colonies with 5, 6, and 14 nests per colony representing 28% of all occupied osprey nests within the study area (Figure 2).

Table 1. Distribution of occupied osprey nest sites in the WRSA

Area	# of nests	% of nests
Finlay Reach	35	40
Finlay Arm	23	26
Ospika Arm	4	5
Omineca Arm	8	9
Parsnip Reach	52	60
Parsnip Arm	20	23
Manson Arm	32	37
Peace Reach	0	0
Peace Arm	0	0
Dinosaur Reservoir	0	0
TOTAL	**87**	**100**

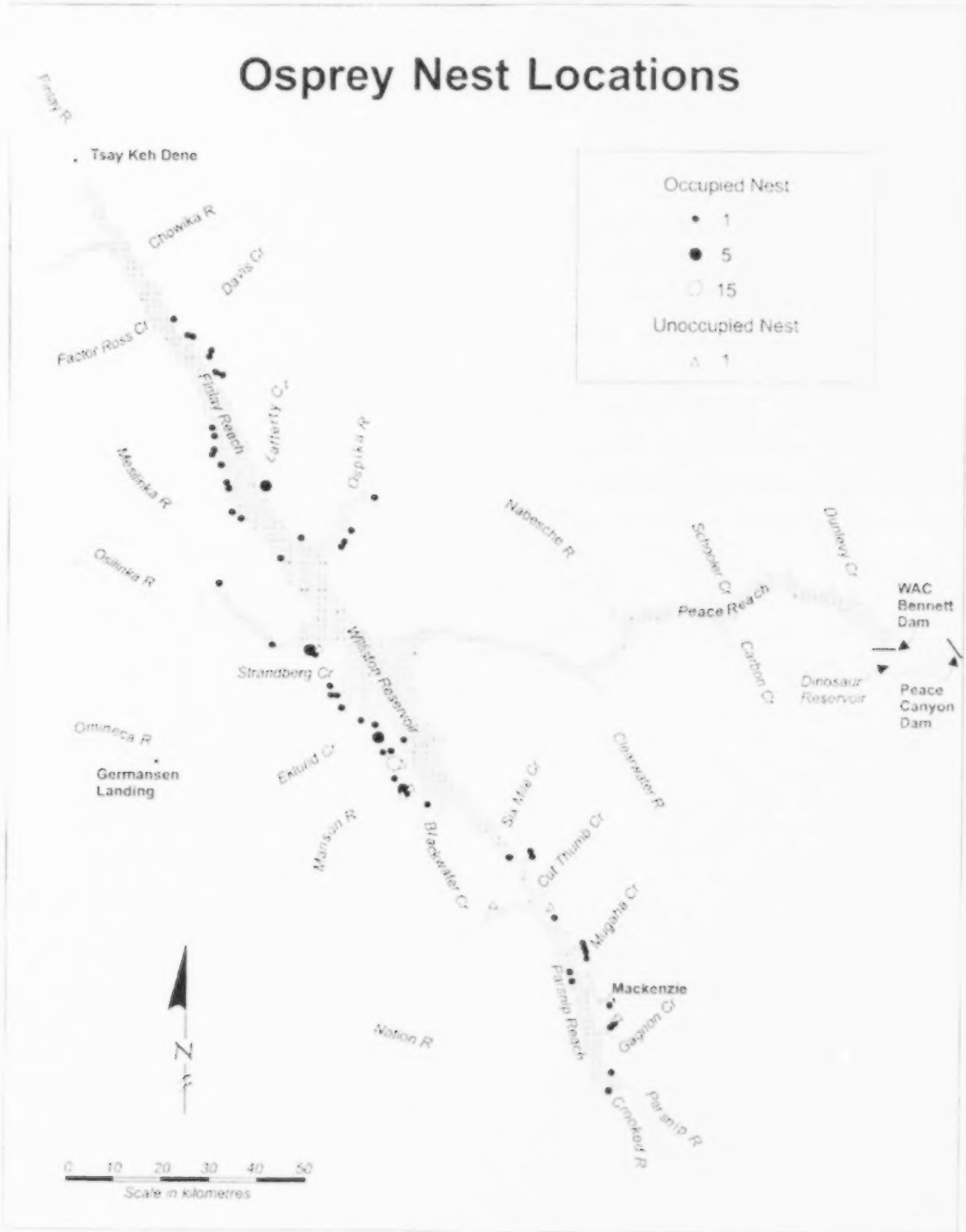

Figure 2. Distribution of occupied osprey nests within the *1995* study area.

Productivity

Nests yielding 1, 2, and 3 fledglings accounted for 10, 26, and 18% of all occupied nests, respectively. No fledglings were observed in 39 (45%) of the occupied nests. For the entire study area the productivity was estimated to be 1.18 ± 0.13 young/occupied nest, and 2.15 ± 0.10 young/successful nest (Table 2).

Productivity was 1.26 ± 0.22 and 1.13 ± 0.16 young/occupied nest and 2.32 ± 0.17 and 2.03 ± 0.13 young/successful nest in the Finlay and Parsnip Reaches, respectively. The productivity of Manson Arm was 0.96 ± 0.21 young/occupied nest and 2.07 ± 0.21 young/successful nest. There was no significant difference in productivity between ospreys occupying the Finlay and Parsnip Reaches (t-test: young/occupied nests - t=0.38, df=87, p=0.64; young/successful nests - t=1.05, df=48, p=0.19). In addition there was no significant difference in the productivity between ospreys occupying Finlay Reach, Manson Arm, and the portion of the Parsnip Reach that excludes Manson Arm (ANOVA young/occupied nest F(2,87)=0.11, p=0.41; young/successful nest F(2,48)= 1.90, p=0.18). The ANOVA for young/successful nest failed Levene's test for homogeneity of variance (Levene test p=0.04). The possible nest failure rate (the percent of occupied nests that either did not produce young, or for which there were no fledgling data) ranged from 25% in the Ospika Arm to 63% in the Omineca Arm (Table 2).

Table 2. Mean number of osprey young produced per occupied and successful nest in the Williston Reservoir Study Area (WRSA).

Area	Occupied nest			Successful nest			
	n	mean	se	n	mean	se	max. nest failure rate (%)
Finlay Reach	**35**	**1.26**	**0.22**	**19**	**2.32**	**0.17**	**46**
Finlay Arm	23	1.30	0.27	13	2.31	0.21	43
Ospika Arm	4	1.75	0.75	3	2.33	0.66	25
Omineca Arm	8	0.88	0.44	3	2.33	0.33	63
Parsnip Reach	**52**	**1.13**	**0.16**	**29**	**2.03**	**0.13**	**44**
Parsnip Arm	20	1.40	0.23	14	2.00	0.15	30
Manson Arm	32	0.97	0.21	15	2.07	0.21	53
Peace Reach	**0**	**0**	**0.00**	**0**	**0**	**0.00**	-
Peace Arm	0	0	0.00	0	0	0.00	-
Dinosaur Reservoir	0	0	0.00	0	0	0.00	-
TOTAL	**87**	**1.18**	**0.13**	**48**	**2.15**	**0.10**	**45**

Nest Tree Status and Species

Occupied osprey nests were found predominately in dead trees compared with live trees (97 % and 3% respectively; Table 3). Seventy-five percent of these nest sites were located in trees not identified to species. The remaining occupied osprey nests were located in dead spruce (10%), dead cottonwood trees (7%), dead pine (2%), live pine, spruce, cottonwood and dead aspen (1% each) (Table 3). Unoccupied osprey nests were also found almost exclusively in dead trees (97% in snags, 3% in live trees). Seventy percent of these nests were located in dead trees of unidentified species. The remaining unoccupied osprey nests were located in dead spruce (12%), dead cottonwood trees (9%), dead pine (2%), live pine, spruce, cottonwood and dead aspen (1% each) (Table 3). Occupied nests in live trees were found only in the Finlay Reach (1 each in Arm; Table 4). Many of the unidentifiable snags were typically emergent trees that have remained standing since the reservoir was flooded in 1967.

Nest Site Position

Osprey nests were most often found in the shoreline areas rather than in upslope areas. Eighty percent of occupied and 79% of unoccupied nests were located in shoreline areas. Occupied nests in upslope regions within the study area were found almost exclusively in the Finlay Reach, whereas nests in the shoreline areas were found most often in the Parsnip Reach, particularly within Manson Arm (Table 5).

Table 3. Occupied and unoccupied osprey nest sites by tree status and tree species.

		Occupied nests		Unoccupied nests	
Tree status	Tree species	#	%	#	%
Dead	Trembling Aspen	0	0	1	1
	Black Cottonwood	7	8	9	9
	Spruce	10	12	12	13
	Lodgepole Pine	2	2	2	2
	Unknown	65	75	70	72
	Total dead	**84**	**97**	**94**	**97**
Live	Trembling Aspen	0	0	0	0
	Black Cottonwood	1	1	1	1
	Spruce	1	1	1	1
	Lodgepole Pine	1	1	1	1
	Unknown	0	0	0	0
	Total live	3	3	3	3

Table 4. Number of occupied osprey nests in live trees and snags by tree species in the WRSA.

Area	Live Tree Species			Snags
	Black Cottonw.	Lodgepole Pine	Spruce	
Finlay Reach	1	1	1	32
Finlay Arm	0	1	0	22
Ospika Arm	1	0	1	2
Omineca Arm	0	0	0	8
Parsnip Reach	0	0	0	52
Parsnip Arm	0	0	0	20
Manson Arm	0	0	0	32
Peace Reach	0	0	0	0
Total	1	1	1	84

Table 5. Distribution of occupied osprey nests by location within the WRSA

Area	Upslope		Shoreline	
	# of nests	% of nests	# of nests	% of nests
Finlay Reach	16	18	19	21
Finlay Arm	14	16	9	10
Ospika Arm	2	2	2	2
Omineca Arm	0	0	8	9
Parsnip Reach	1	1	51	59
Parsnip Arm	1	1	19	22
Manson Arm	0	0	32	37
Peace Reach	0	0	0	0
Totals	17	20	70	80

Bald Eagles

Nest Site Density and Distribution

Sixty-one nest sites in the WRSA were identified as bald eagle nests during the 1995 surveys, of which, 36 (60%) were both occupied and active. Twenty-three of the occupied nests (64%) were successful, while the remaining 13 nests (36%) had either failed or had already fledged young by the time of the third

aerial survey. The overall density of occupied nests was 0.02 occupied nest sites per km of shoreline, or one occupied nest site for every 51 km of shoreline.

The distribution of occupied bald eagle nest sites was fairly uniform between the Finlay, Parsnip and Peace Reaches of Williston Reservoir (42%, 33% and 25% of occupied nests , respectively) (Table 6, Figure 3). Three of the nine bald eagle nests in the Peace Reach were located along Dinosaur Reservoir. Average intraspecific nearest neighbour distances for occupied nest sites 8.8 km (± 1.7 km; range 2.4-30.5) for bald eagles.

Productivity

Nests yielding 1 and 2 fledglings accounted for 42% and 22% of all occupied nests, respectively. No fledgling data were available for 13 (36%) of the occupied nests. We estimated the productivity of the Williston Reservoir bald eagle population to be 0.86 ± 0.13 young/occupied nest and 1.35 ± 0.10 young/successful nest (Table 7). Productivity in the Finlay, Parsnip and Peace Reaches ranged from 0.50 to 1.13 young/occupied nest and 1.14 to 1.55 young/successful nest. There was no significant difference in productivity of bald eagles occupying the Finlay, Parsnip and Peace Reaches (ANOVA: young/occupied nest $F(2,35)=2.51$, $p=0.10$; young/successful nest $F(2,22)=1.90$, $p=0.18$). As with ospreys, the ANOVA for young/successful nest failed Levene's test for homogeneity of variance (Levene test $p=0.04$). Sample sizes were too small to statistically compare productivity between arms of the study area. The possible nest failure rate (the percent of occupied nests that either did not produce young, or for which there were no fledgling data) ranged from 0% in the Ospika Arm to 67% in the Parsnip Arm (Table 7).

Table 6. Distribution of occupied bald eagle nest sites in the WRSA

Area	# of nests	% of nests
Finlay Reach	**15**	**42**
Finlay Arm	13	36
Ospika Arm	2	6
Omineca Arm	0	0
Parsnip Reach	**12**	**33**
Parsnip Arm	9	25
Manson Arm	3	8
Peace Reach	**9**	**25**
Peace Arm	6	17
Dinosaur Reservoir	3	8
TOTAL	**36**	**100**

Figure 3. Distribution of occupied bald eagle nests within the 1995 study area.

Table 7. Mean number of bald eagle young produced per occupied and successful nest in the WRSA.

Area	Occupied nest			Successful nest			
	n	mean	se	n	mean	se	max. nest failure rate (%)
Finlay Reach	**15**	**1.13**	**0.21**	**11**	**1.55**	**0.16**	**27**
Finlay Arm	13	1.00	0.23	9	1.44	0.18	31
Ospika Arm	2	2.00	0.00	2	2.00	0.00	0
Omineca Arm	0	0.00	0.00	0	0.00	0.00	0
Parsnip Reach	**12**	**0.50**	**0.19**	**5**	**1.20**	**0.20**	**58**
Parsnip Arm	9	0.33	0.17	3	1.00	0.00	67
Manson Arm	3	1.00	0.58	2	1.50	0.50	33
Peace Reach	**9**	**0.89**	**0.20**	**7**	**1.14**	**0.14**	**22**
Peace Arm	6	1.00	0.26	5	1.20	0.20	17
Dinosaur Reservoir	3	0.67	0.33	2	1.00	0.00	33
TOTAL	**36**	**0.86**	**0.13**	**23**	**1.35**	**0.10**	**60**

Nest Tree Species

Occupied bald eagle nests were located more often in live trees than in dead trees (78 % in live trees, 22 % in dead trees) and unoccupied bald eagle nests were found more often in live trees than in dead trees, 85% and 15%, respectively (Table 8). Live trembling aspen and black cottonwood were the two most common tree species that contain occupied eagle nests (36% of occupied nests in each species). Most unoccupied nests were found in live deciduous trees (31% in live aspen and 50% in live cottonwood) (Table 8). Occupied nests were located in different tree species in different reaches of the WRSA (Table 9). Live trembling aspen was used more often than cottonwood in the Finlay Reach while cottonwoods were used more often in the Parsnip Reach. Occupied nests were found almost evenly in live trembling aspen and cottonwood in the Peace Reach (Table 9).

Nest Site Position

Occupied and unoccupied bald eagle nests were found most often in upslope areas. Eighty-six percent of occupied and 92% of unoccupied nests were located in upslope areas. Occupied nests in upslope regions of the study area were fairly evenly distributed between the 3 main reaches. Occupied nest sites in the shoreline area were found in low numbers in the Parsnip and Finlay Reaches. No occupied nests were found in the shoreline area of the Peace Reach (Table 10).

Table 8. Occupied and unoccupied bald eagle nest sites by tree status and tree species.

		Occupied nests		Unoccupied nests	
Tree status	Tree species	#	%	#	%
Dead	Trembling Aspen	3	5	4	7
	Black Cottonwood	2	[illegible]	2	3
	Spruce	0	0	0	0
	Lodgepole Pine	0	0	0	0
	Unknown	3	[illegible]	3	5
	Total dead	**8**	**22**	**9**	**15**
Live	Trembling Aspen	13	36	19	31
	Black Cottonwood	13	36	31	50
	Spruce	1	3	1	2
	Lodgepole Pine	1	3	1	2
	Unknown	0	0	0	0
	Total live	**28**	**78**	**52**	**85**

Table 9. Number of occupied bald eagle nests in live trees and snags by tree species in the WRSA.

	Live tree species				Snags
Area	Trembling Aspen	Black Cottonwood	Lodgepole Pine	Spruce	
Finlay Reach	**6**	**3**	**0**	**1**	**5**
Finlay Arm	5	2	0	1	5
Ospika Arm	1	1	0	0	0
Omineca Arm	0	0	0	0	0
Parsnip Reach	**2**	**6**	**1**	**0**	**3**
Parsnip Arm	2	4	1	0	2
Manson Arm	0	2	0	0	1
Peace Reach	**5**	**4**	**0**	**0**	**0**
Peace Arm	4	2	0	0	0
Dinosaur Reservoir	1	2	0	0	0
Total	**13**	**13**	**1**	**1**	**8**

Table 10. Distribution of occupied bald eagle nests by location within the WRSA

	Upslope		Shoreline	
Area	# of nests	% of nests	# of nests	% of nests
Finlay Reach	**12**	**34**	**3**	**8**
Finlay Arm	10	28	3	8
Ospika Arm	2	6	0	0
Omineca Arm	0	0	0	0
Parsnip Reach	**10**	**28**	**2**	**3**
Parsnip Arm	8	22	1	3
Manson Arm	2	6	1	3
Peace Reach	**9**	**25**	**0**	**0**
Peace Arm	6	17	0	0
Dinosaur Reservoir	3	8	0	0
Totals	**31**	**86**	**5**	**14**

DISCUSSION

Ospreys

Nest site density and distribution

Differences in the gross habitat types (coastal, interior lake, interior river, man-made reservoirs) and in the way that osprey breeding densities are reported in the literature make comparisons to other populations difficult. None the less, density of ospreys within the WRSA is similar to other reported densities (Table 11). Most densities reported in Table 11 are for fairly large areas that probably include large amounts of land area unoccupied by osprey nests. However, when compared with a population inhabiting a man-made reservoir in Montana (Grover 1984), the WRSA osprey nesting density is low.

Poole (1989) suggested that breeding density is controlled to a great extent by the availability of stable, predator free nest sites. Water management that leads to flooding often results in the isolation of standing trees that appear to attract nesting ospreys presumably for the security from predation that they provide (Henny and Noltmeier 1975, Hagan 1984 as cited in Poole 1989). Emergent snags within Williston Reservoir provide such sites for nesting ospreys and may be contributing to larger osprey populations than were present prior to water impoundment. Other parameters limiting osprey density are related to factors affecting productivity as discussed below.

Table 11. Osprey breeding densities from other studies in North America

Authority	Location	Density occupied, nests per km of river or per 100 km r
Grover 1984	Montana	0.22 pairs km of shoreline
Bider and Bird 1983	Quebec	0.41 pairs/100km^2
Wetmore and Gillespie 1976	Quebec	1.2 pairs/100km
Saurola 1983	Finland	0.27-0.30 pairs/100km^2
This Study	**Northcentral B.C.**	**0.05 pairs/km shoreline**

Productivity

One estimation of productivity that we calculated was young per successful nest, however, because it does not take nest failures into account, it overestimates productivity (Steenhof 1987). As a result, we can not make comparisons between the productivity of this population and other osprey or bald eagle populations using this estimator. The second estimate of productivity that we calculated was the number of young/occupied nest, which is a more widely accepted estimator of productivity (Steenhof 1987). Given that we assumed that all nest sites where no fledgling data were available actually represented nest failures, our young/occupied nest estimate represents the "worst possible" productivity for the nest sites analyzed.

Our estimate of productivity based on young/successful nest is at the high end when compared to other North American populations (Table 12). Our estimate of minimum productivity based on young/occupied nest falls in the middle of the range (Table 12), as does our maximum estimate of nest failure rate (Table 12). Comparisons between some of the data reported in Table 12 and our data should be made with caution. Much of the historical data from other North American populations was collected at a time when many of these populations were recovering from various human-induced declines. If we compare our data to more recent data (Steeger *et al.* 1992, USDA Forest Service 1988, Hagan and Walters 1990 - all reported in Table 12), productivity of the Williston osprey population is similar.

It has been estimated that, to be stable, a population of nesting ospreys should fledge between 0.95 and 1.30 young/breeding pair/year based on an analysis of mortality rates in several northeastern US populations (Henny and Wight 1969). Even our lowest estimate of 1.19 young/occupied nest fits well within this range. Given that mortality rates for the WRSA ospreys may not be equivalent to those determined by Henny and Wight (1969), we are unsure at this stage as to whether the Williston population is declining, stable, or growing. Mortality rates may be higher for Williston ospreys, especially during migration periods, given that Williston ospreys have to migrate greater distances than those studied in the eastern US. Productivity rates in excess of 1.30 young/breeding pair/year may be required to provide for a stable or growing population in Northeastern BC. Ospreys breeding in Finland (60° - 70° N latitude) had

Table 12. Osprey productivity and nest failure rate from this study and other studies in North America.

Authority	Location	Year(s) data collected	Coastal or interior system (C or I)	Aquatic system[1]	Young per occupied nest	Young per successful nest	# of nests	% of nests that failed
Hughes 1982	Alaska	1976-1980	C	O	.42	2.12	12	30.4
Van Daele and Van Daele 1982	Idaho	1978-1980	I	RE	.27	2.00	144	32.0
Steeger *et al.* 1992	Southeastern BC	1987-1988	I	RE	.40	2.10	162	29.2
USDA Forest Service 1988	Eastern Region	1980-1988	-	-	0.94	1.66	2080	43.7
Hagan and Walters 1990	North Carolina	1983-1985	C	O,R	.15	-	130	-
Sleidl *et al.* 1991	New Jersey	1987-1988	C	O	.21	1.69	62	32.3
Grover 1984	Montana	1981-1982	I	RE	.12	2.16	83	48.2
Judge 1983	Mexico	1977-1978	C	O	0.87	.66	67	47.8
Stocek and Pearce 1983	New Brunswick	1974-1980	C,I	O,R	.10	.80	133	39.0
Seymour and Bancroft 1983	Nova Scotia	1975-1981	C	O	.22	.87	237	43.2
Flook and Forbes 1983	Southeastern BC	1981	I	L,R	1.50	-	27	-
Henny *et al.* 1977	New Jersey	1968-1975	C	O	0.31	.43	297	78.0
Henny *et al.* 1977	Delaware	1970-1975	C	O	1.09	.96	118	44.4
This Study	Northcentral B.C.	1995	I	RE	1.18	2.15	87, 48	55.0

[1] O=ocean, RE=reservior, L=lake, R=river

productivity rates of 1.3 - 1.5 and 2.0 - 2.2 young per occupied and successful nests, respectively, and appeared to maintain a fairly stable population size between 1971 and 1980 (Saurola 1983). Although Williston Reservoir is slightly to the south of the Finnish population (between 55° and 57° N latitude), comparing the Williston population with the Finnish population may be more appropriate than with north eastern US populations.

Factors reported to affect osprey productivity (and density) include: limited food resources (Kushlan and Bass 1983, Poole 1982, Hagan 1986), inclement weather (MacCarter and MacCarter 1979, Van Daele and Van Daele 1982), disease (Poole 1989), interspecific competition (Hughes 1982, Ogden 1975), predation on eggs and chicks by cervids and owls (MacCarter and MacCarter 1979, Hughes 1982), human disturbance (Van Daele and Van Daele 1982, Levinson and Koplin 1984, Hughes 1982), environmental contamination (MacCarter and MacCarter 1979, Henny 1983) and the availability of nesting habitat (Rhodes 1972, Little 1994). Forage quality and foraging energetics have been identified as factors that can determine productivity of ospreys by some authors (Poole 1982, Hagan 1986) but these factors have been refuted by others (Steeger *et al.* 1992, MacCarter and MacCarter 1979).

Many of the above factors affect productivity by inducing egg failure (Steidl *et al.* 1991, Levenson and Koplin 1984). Egg viability can be affected through environmental contamination where eggshell thinning and altered gas exchange across shell surfaces and membranes ultimately leads to egg failure. Low hatching success can also be caused by insufficient or irregular incubation. Human activity in the vicinity of nests can prevent proper incubation of eggs by displacing birds from nests (Levenson and Koplin 1984) . Repeated disturbances can be very detrimental. Harassment from other avian species can also negatively affect productivity: Cervids and owls can harass ospreys to the point where hatching success is compromised (Levenson and Koplin 1984).

Breeding chronology is thought to affect osprey productivity in more subtle ways. Initiation of reproduction early in the breeding season has been shown to result in greater fledgling production (Steeger and Ydenberg 1993, Steeger *et al.* 1992, Judge 1983). Initiation of clutches within the Williston osprey population is likely asynchronous across all nesting pairs. Variability in productivity within Williston Reservoir ospreys may be partially explained by this phenomenon.

At this point it is unclear which, if any, of the above factors may be affecting the productivity of ospreys within the Williston Reservoir. In addition, we are uncertain if the osprey population is increasing, decreasing or stable.

Nest Site Selection

The predominance of osprey nest sites in dead trees is consistent with other studies that have examined osprey nesting sites (Smith and Ricardi 1983, Van Daele and Van Daele 1982, Steeger *et al.* 1992). Ospreys have also been noted to nest in artificial structures such as hydro poles and artificial nesting

platforms (MacCarter and MacCarter 1979, Steenhof 1987). Where abundant, ospreys have been known to prefer suitable man-made structures over naturally occurring nesting habitat (Steeger *et al.* 1992).

Osprey nests were located most often in shoreline habitat (Table 5) where emergent snags from the flooding of the major rivers in the area are concentrated. Use of shoreline habitat has been noted throughout the range of the osprey. The use of emergent trees or snags as a result of flooding for nesting habitat has been observed in numerous areas (Henny and Noltmeier 1975, Hagan 1984 as cited in Poole 1989, Grover 1984).

Colonial Nesting

No clear definition of conditions representing colonial nesting has been presented for ospreys, however, it is recognized that, in some instances, numerous ospreys (as many as 300; Greene 1987) nest in close proximity to each other and function as a colony. Flemming *et al.* (1991) determined that, for ospreys nesting in an estuary in Antigonish County, Nova Scotia, Canada, mean internest distance for colonial nesters was 0.7 km and that some nests were as close as 300 m to the nearest conspecific nest. Although there is some speculation as to why colonial nesting may have evolved in ospreys, it is evident that there are many adaptive advantages associated with it. Colonially nesting species often experience reduced losses to predation (Hagan and Walters 1990). Flock foraging can improve foraging success and gains in foraging efficiency can lead to improved productivity (Flemming *et al.* 1991). For ospreys, the recruitment of flock mates for social foraging, and hence the benefits of social foraging is more likely in colonially nesting ospreys (Flemming *et al.* 1991). Colonial breeding and associated flock foraging are particularly adaptive when prey occur in clumped distributions (Greene 1987). These situations occur when fish species school, spawn or use forage sources that are clumped. It is unclear if and how the osprey colonies within the WRSA benefit from colonial nesting or whether colonial nesting is an artifact of nest site availability. For the colonies found in the WRSA, nearest neighbour distances between osprey nests were as short as 50 m.

Effects of Reservoirs on Ospreys

Construction of dams for hydroelectricity, irrigation and wildlife habitat enhancement has created many artificial reservoirs across North America. It is believed that reservoir development has been responsible for much of the breeding range expansion for ospreys throughout the western US (Roberts and Lind 1977, Poole 1989, Van Daele and Van Daele 1982, Henny 1983). Osprey density was significantly greater on reservoirs as compared to free flowing river sections in both Oregon and Montana (Roberts and Lind 1977, Grover 1984).

The creation of reservoirs affects several parameters important to osprey breeding density, most notably nesting habitat and food availability. Trees not harvested prior to flooding often provide suitable nesting sites for ospreys in the shallow inundation zones. Further, water level management within reservoirs can alter the distribution of fish, resulting in the development of a very productive shallow water fishery in the

bays. Shallow water fisheries can provide an abundant food supply for piscivorous birds (Van Daele and Van Daele 1982, Flook and Forbes 1983, Grover 1984).

Data collected during this study suggest that the number of suitable nest sites for ospreys in the WRSA may have increased. This observation is based on the nest site selection by breeding pairs in the study area. Most breeding pairs have occupied emergent snags in shallow water, while very few have been found nesting in free flowing riverine areas or upslope. A combination of the increased abundance of nest-sites, and the likely creation of a shallow water fishery in some of the embayments has undoubtedly contributed to the size and success of the osprey breeding population within the WRSA.

It is widely accepted that levels of mercury increase in fish after the formation of reservoirs. Like other reservoirs in North America, elevated levels of mercury have been detected in fish taken from Williston Reservoir (Watson 1992). Of concern in the Williston Reservoir is that some fish species are known to have significant levels of mercury in their tissues (several species were found to exceed the medically significant level of 0.2 ppm, and the federal guideline for commercial fisheries of 0.5 ppm; Watson 1992). Since fish are likely a large part of the diet of ospreys and eagles in the WRSA, the bioaccumulation of mercury in fish and hence ospreys, may represent a potential factor that could influence the productivity of these raptor species.

Bald eagles

Density and Distribution of Nest Sites

The recorded density of occupied bald eagle nest sites in the WRSA (0.02 occupied nest/km of shoreline) is equal to the lowest of other studies (Table 13). Several of these studies are specific to coastal bald eagle populations. If we compare the WRSA density to those studies pertaining only to interior bald eagle populations, it is somewhat more comparable, but still equal to the lowest of other bald eagle populations in the interior of British Columbia. This is true for both lake and river bald eagle nesting populations.

Densities of bald eagle nesting territories are governed by several factors. These include the availability of food (Gerrard *et al.* 1983; Dzus and Gerrard 1993; Hansen 1987); development of shoreline areas (Dzus and Gerrard 1989); stream gradient (Blood and Anweiler unpubl); human activity (Fraser *et al.* 1985; McGarigal *et al.* 1991) and the availability of nesting sites (Newton 1979; Corr 1974; Hodges *et al.* 1984; Dzus and Gerrard 1989). Two factors, the availability of food and the amount of nesting habitat, whichever is in shortest supply, can exert a strong influence on nesting densities (Newton 1979). Where nesting sites are readily available, nesting pairs tend to be evenly spaced, with distances between pairs correlated with differences in food supply (Newton 1979; Gerrard *et al.* 1983). This is mainly due to the fact that breeding eagles have to remain near nest sites to forage. If a reliable food source is not available, the area

will not support a nesting pair (Hansen 1987). Conversely, where available nesting sites are limited, populations may exist at lower densities than the food supply could support (Newton 1979).

Table 13. Bald eagle breeding densities from other studies in North America.

Authority	Location	Occupied nests per km shoreline
	Interior B.C. and Yukon Rivers	
Blood and Anweiler (unpublished)	Kootenay R. (Goat Cr-Kootenay Lk)	0.10
Blood and Anweiler (unpublished	Nechako River above Stuart R.	0.09
Blood and Anweiler (unpublished)	Columbia R. (Athalmer-Donald)	0.09
Blood and Anweiler (unpublished)	Morice R. (Gosnell Cr-Owen Cr)	0.08
Blood and Anweiler (unpublished)	Swift R. (Swan Lk-Coconio Cr)	0.08
Blood and Anweiler (unpublished)	Koidern R. (White R.-Edith Cr)	0.07
Blood and Anweiler (unpublished)	Kluane R (below Kluane Lk)	0.06
Blood and Anweiler (unpublished)	Yukon R. (below Marsh Lk)	0.06
Blood and Anweiler (unpublished)	Peace R. above Moberly R.	0.04
	Interior B.C. and Yukon Lakes	
Blood and Anweiler (unpublished)	Squanga Lake	0.09
Blood and Anweiler (unpublished)	Pine Lake	0.08
Blood and Anweiler (unpublished)	Sulphur Lake	0.07
Blood and Anweiler (unpublished)	Cheslatta/Murray Lakes	0.03
Blood and Anweiler (unpublished)	Nanika/Kidprice/Stepp Lakes	0.02
This Study	**Williston Reservoir**	0.02
	West Coast Regions	
Hodges and Robards (1982)	SE Alaska	0.50
Hansen(1987)	Chilkat Valley, Alaska	0.38
Corr(1974)	Alaska	0.16
Hansen and Hodges (1985)	SE Alaska	0.15
McGarigalet. al. (1991)	Columbia River Estuary	0.14
Farr (1988)	Fraser valley, B.C.	0.12
Vermeer *et al* (1987)	Gulf Islands, B.C.	0.12
Hodges *et al.* (1984)	South coastal B.C.	0.09
Vermeer and Morgan (1989)	Barkley Sound	0.09
Hodges *et al.* (1984)	North coastal B.C	0.08
Lueke-Joyce(1988)	Vancouver I	0.02
	Southern U.S. Interior	
Swenson *et a/.* (1985)	Greater Yellowstone Ecosystem	0.04

One factor that can affect the quality of nesting habitat is the gradient, or flow rate of a river. Riverine areas with a low gradient are typically meandering in nature and generally have a well developed and highly complex flood plain. These floodplain areas provide ample nesting sites (large deciduous trees) and a diversity of prey species (e.g., ducks and fish). High gradient riverine areas, on the other hand, lack this habitat complexity and tend to support fewer bald eagle nesting pairs than low gradient river areas (Blood and Anweiler unpubl). At this point it is difficult to determine which of the various factors are contributing to the relatively low density of eagle nest sites in the WRSA. Flooding of the three major rivers to form the WRSA has undoubtedly changed the availability of suitable nesting and foraging habitat. However, there are some areas of cottonwood trees that appear to be suitable nesting habitat, but are unused at present. Flooding has also likely altered the distribution, abundance and composition of prey species within the study area in ways that may either be beneficial or detrimental to bald eagles. As a result, it is not possible to conclude if bald eagle numbers are low, or if the study area is at, or near the carrying capacity.

Productivity

The estimation of productivity that we were able to determine (young/successful nest) falls at the low end of the range of productivity data from other areas of North America as does the estimate of young/occupied nest (Table 14). However, our assumed maximum nest failure rate of 37% falls well within the range of nest failures noted in other bald eagle productivity studies (Table 14). While our estimate of 0.86 young/occupied nest is below that for many other bald eagle populations, it is still higher than the minimum of 0.7 young/occupied nest site required to maintain a stable bald eagle population (Sprunt *et al.* 1973).

Factors that can affect productivity include: availability of food (Bangs *et al.* 1982, Hansen 1987); the influence of conspecific breeding pairs (Anthony *et al.* 1994); competition from nonbreeding eagles (Hansen 1987); environmental contaminants (Mickey and Anderson 1968, Wiemeyer *et al.* 1984, Anthony *et al.* 1994; Elliott 1995); human disturbance (Anthony *et al.* 1994); logging or clearing of land near nest sites (Booth and Farr 1993, Anthony and Issacs 1989); habitat loss due to residential development (Therres *et al.* 1993); and egg collection (Wood and Collopy 1993, Booth and Farr 1993). Studies examining the effect of human disturbance on bald eagle nesting success have yielded variable results. Mathisen (1968), McEwan and Hirth (1979) and Fraser *et al.* (1985) found that human activities (such as recreational activities, flogging activity, pedestrian and vehicular traffic) had no negative effect on eagle nesting success, whereas Grubb (1980), Nash *et al.* (1980), Gerrard *et al.* (1985), and Anthony and Issacs (1989) reported the opposite.

At this point it is impossible to know what factor(s) is/are having the greatest impact on the productivity of this population. In addition, it is not known whether this population is declining, stable or increasing. Discussions pertaining to the productivity of this population should consider that the nesting

Table 14. Bald eagle productivity from other studies.

Authority	Location	Year(s) data collected	Natural system or reservoir (N or R)	Coastal or Interior system (C or I)	Aquatic system	Young per occupied nest	Young per successful nest	# of nests	% of nests that failed
British Columbia									
Elliott (1995)	Clayquot Sound	1992-1994	N	C	O	0.81	1.21	101	73
Elliott (1995)	Barkley Sound	1992-1994	N	C	O	0.87	1.34	101	57
Elliott (1995)	SE Vancouver I	1991-1994	N	C	O	0.97	1.58	125	37
Elliott (1995)	S. Moresby I	1994	N	C	O	0.32	1.20	19	74
Elliott (1995)	Fraser Delta	1993-1994	N	C	O	1.30	1.63	20	14
Elliott (1995)	Langara I.	1994	N	C	O	0.73	1.23	22	41
Elliott (1995)	Fraser Valley	1992-1994	N	C	R	1.30	1.51	62	13
Elliott (1995)	Johnstone Strait	1991-1994	N	C	O	0.34	1.14	97	69
Elliott (1995)	Powell River	1992-1994	N	C	O	0.88	1.45	97	39
Farr (1988)	Fraser valley, B.C.	1986-1988	N	C	R	1.43	1.74	39	*
Blood and Anweiler (1990)	S.W. Yukon	-	N	I	R	1.10	1.50	39	*
Forbes and Kaiser (1984)	CVWMA[2]	1982		I	R.L	1.40	1.50	11	9
This Study	**N. Central B.C.**	**1995**	**R**	**I**	**RL**	**0.86**	**1.35**	**36,23**	**60**
Western United states									
WSFW[3] (unpublished data)	Washington State	1995				0.99[4]	-	-	
WSFW (unpublished data)	Washington State	1994				0.92	1.46	627	
WSFW (unpublished data)	Washington State	1986-1994				1.03	-	7754	35
McAllister *et al.* (1986)	Washington State	1981-1985				0.87	1.42	173	34
Isaacs and Anthony (1996)	Oregon State	1990-1996				0.95	1.56	1526	*
Isaacs *et al.* (1983)	S. Oregon	1978-1982				0.92			
Anderson (1985)	S. Central Oregon	1971-1984				0.95	1.50	169	
Bernatowicz *et al.* (1996)	S. Central Alaska	1989-1990	N	C	O	0.36-1.20[5]	-	1821	-
Ritchie (1982)	S. Alaska	1978-1979	N	I	R	1.16	1.73	28	
Bangs *et al.* (1982)	Alaska	1979-1980	N	I	R	1.29	-	55	
Other North American areas									
Kralovec *et al.* (1992)	Colorado and SE Wyoming	1981-1989		I		1.21	1.91	85	
Swenson *et al.* (1985)	GYE[6]	1972-1982	N R	I	RE R L	1.02	-	50	
USDA Forest service (1988)	USNF[7] -E. Region	1980-1988	-	-	-	1.11	1.60	4227	30-36
Buehler *et al.* (1991)	Chesapeake Bay	1981-1990	N	C	O	1.18	1.71	1448	20-41
Austin South and Dickie (1986)	Nova Scotia	1986	N	I	R	1.00	1.66-1.71	260	41
Gerrard *et al.* (1983)	Saskatchewan	1968-1981	N	I	L	1.17	-		
Grier *et al.* (1983)	Minnesota	1981	N	I	L	1.27	-		-
McEwan and Hirth (1979)	N Florida	1973-1976	N	I	LR	1.14	1.59	189	-

O=Ocean, R = river, L = lake, RE = reservoir, [2] CVWMA=Creston Valley Wildlife Management Area, [3] WSFW=Washington State Dept of Fish and Wildlife
[4] data only for areas that have had historically low productivity due to environmental contaminants, [5] productivity data from the area affected by the *Exxon Valdez* oil spill,
[6] GYE =Greater Yellowstone Ecosystem, [7] USNF=U.S. National Forests

success of bald eagles is highly variable in undisturbed areas and has also been demonstrated to be geographically variable (Elliott 1995).

Nest Tree Species

Tree species used by nesting bald eagles is extremely variable (Table 15). Our findings of eagles nesting predominantly in live deciduous trees is consistent with other studies in similar habitat types. Because of the variability of tree species used, it is generally believed that tree structure, rather than species is the most important factor governing nest tree selection (Gerrard *et al.* 1975).

Trees that bald eagles select for nest sites are generally taller and larger in diameter than surrounding stand conditions, often extending above the canopy (Andrew and Mosher 1982; Green 1985; Anthony *et al.*

Table 15. Variation in nest tree species and sizes for Bald eagle nest trees

					Mean nest tree size	
Authority	Location	Nest tree species[1]	# of nests in each species	Proportion (%)	dbh[2] (sd) (cm)	height (sd) (m)
Blood (1989)	Vancouver I.	Fd	59	94	133.6(37.3)	35.9(10.6)
		Fg	3	5	91.3 (8.0)	39.7(7.3)
		Ct	1	1	153.0 (0.0)	42.5 (0.0)
Booth and Farr (1993)	Fraser Valley	Fd	17	47	158.2 (68.9)	43.0(13.3)
		Ct	17	47	114.8 (42.6)	34.8 (7.9)
B.C. Ministry of Environment (1989)	Fraser Valley	Ct	9	56	141.0 (17.9)	34.2 (2.7)
		Fd	5	31	174.2 (12.9)	46.0 (2.6)
		Ss	1	6	138.0(0.0)	38.0 (0.0)
		Mb	1	6	109.0 (0.0)	27.0 (0.0)
Oneil(1988)	Vancouver I.	Fd	35	56		
		Ss	21	30		
		Cr	11	16		
		Ot	3	4		
			(n=70)		164.8 (66.9)[3]	44.4 (11.2)[3]
Anthony and Issacs (1989)	Oregon	Fd, Ss	n/a[4]	n/a		
			(n=24)		170.7 (48.1)[3]	56.5 (12.5)[3]
Vermeer *et al.* (1987)	Gulf islands, B.C.	Fd	35	100	110.6 (25.2)[3]	39.8 (10.8)[3]
Dzus and Gerrard (1993)	Besnard L. Sask	At, Sw Cb, Pj	(n=31)	n/a	41.0 (8.1)[3]	20.2 (4.1)[3]
	Nemeiben L., Sask.	At, Sw Cb, Pj	(n=10)	n/a	44.9 (1.6)[3]	22.8 (3.9)[3]
Forbes and Kaiser (1984)	Columbia Valley, B.C.	Ct	25	96	n/a[4]	n/a
		Fd	1	4	n/a	n/a
Siddle (1990)	Peace River, B.C.	Ct	5	100	n/a	n/a

[1] Fd=Douglas fir; Fg=grand fir; Ct=black cottonwood; Ss=Sitka spruce; Cr=western redcedar; At=trembling aspen, Sw= white spruce, Cb=balsam poplar, Ot=other; Mb=bigleaf maple, Pj=jack pine

[2] dbh=diameter at breast height; [3] all species combined; [4] n/a=measurements not taken; or data not available

1982.; Dzus and Gerrard 1993; Stalmaster 1987; Anthony and Issacs 1989; Kralovec *et al.* 1992). Nest trees are often forked near the crown and frequently have live foliage extending above the nest (Mathisen 1983; Stalmaster 1987). These trees ensure adequate support for a nest, provide an open flight path to and from the nest and provide an unobstructed view of the surrounding area (Green 1985; Stalmaster 1987). Being tall, dominant, codominant or supercanopy trees often means that the nest trees are past their prime and are at various stages of decay (Mathisen 1983), and, as a result, have a limited additional life expectancy. Longevity also depends on tree species, weight of nest, and local weather patterns (Anderson 1985). For example, in Minnesota and Michigan, Mattson and Grewe (1976) estimated that, once a tree is established as a nest tree, it survives for an additional 9.5 years as a nest tree. In Saskatchewan, Gerrard *et al.* (1983) reported a 10% loss of nest trees per year.

Nest Site Location

In most cases bald eagle nests are within 200-300 m of water (Dzus and Gerrard 1993; Corr 1974; Mathisen 1983; Vermeer *et al.* 1987; Oneil 1988; Booth and Farr 1993). Some nests have been found up to 1.5 km from water (McEwan and Hirth 1979). Selection of nest sites at greater distances from water are often associated with a lack of suitable nest sites along the shores of lakes (Stalmaster 1987). In the WRSA, bald eagles tended to nest in areas upslope of the shoreline (Tables 10). This is likely due to the inundation and subsequent destruction of riverine habitat when Williston Reservoir was created. There are, however, numerous areas of presumably suitable deciduous habitat that were identified during helicopter flights in 1995 that are not currently occupied. At this point it is unclear why these areas are not being used by bald eagles.

Effects of Reservoirs on Bald Eagles

Unlike the contention that ospreys benefit from the construction of reservoirs, the effects of reservoir construction on bald eagle populations is unclear. In the WRSA the flooding of the Parsnip, Peace and Finlay Rivers resulted in two major changes in aquatic habitat. Firstly, long stretches of meandering riverine habitat would have been converted to large lake habitat, and secondly, there was likely a corresponding change in the composition and abundance of the waterfowl and fish communities. These two changes in habitat structure may have had confounding effects on the population of breeding bald eagles.

Creation of Williston Reservoir likely reduced the availability of optimal nesting habitat that would have been found along the meandering stretches of the Peace, Parsnip and Finlay Rivers. This change in habitat could have led to a reduction of the breeding density of bald eagles. Flooding of these three rivers has created up to 1800 km of lakeshore habitat. Lakes have been known to support fairly large breeding populations of bald eagles throughout North America (Swensen *et al.* 1985, Kralovec et. al 1992, Blood and Anweiler Unpubl., Gerrard *et al.* 1983). However, the shorelines of natural lakes are typically much different than along man-made reservoirs. Shorelines of natural lakes are riparian zones that develop as a result of natural successional processes. Riparian zones are typically characterized by white spruce and cottonwood

overstory trees in natural riparian habitats near the WRSA. Much of the shoreline of the WRSA contains unnatural riparian vegetation due to rapid flooding and no time for natural successional processes. The shoreline frequently consists of dry pine forest typical of upland habitat. Natural lakes typically have a more gradual transition zone between the lake and the shoreline, resulting in an aquatic habitat with shallow bays suitable for both fish and waterfowl and in many instances large, particularly deciduous trees, in close proximity to the lake that would supply appropriate nesting sites. The shoreline of Williston Reservoir represents less than optimal habitat for bald eagles, as there are few places where large deciduous trees persist. Most eagles in the WRSA tended to nest in the upslope regions of the reservoir rather than along the shoreline.

The effects on the change in distribution and composition of prey species on bald eagle populations is difficult to assess. Without prior knowledge regarding the diets of bald eagles in the area, the elimination of valuable waterfowl habitat due to flooding is unclear. The same is true for the potential changes in the fish community. It is unclear whether flooding has removed a significant source of food for eagles, or has provided a new and more easily accessible prey population. In fact, the potential negative effects of flooding on prey populations may have been compensated by the creation of productive shallow water fisheries that can follow the creation of reservoirs (Van Daele and Van Daele 1982, Grover 1984).

The availability of these shallow water fisheries is often localized in nature and, as a result, they are most beneficial to species that are capable of exploiting them. For example, ospreys are readily able to exploit these areas because of their tendency to nest colonially, whereas, bald eagles, which are far more territorial than ospreys, cannot.

As for the ospreys, bald eagles may be affected by increases in mercury levels following reservoir formation. The bioaccumulation of mercury can negatively affect raptorial birds in numerous ways. Sub-lethal levels of mercury can negatively affect growth, development, reproduction, metabolism and behaviour (Heinz 1979; Eisler 1987). Mercury has also been identified as a direct agent of mortality (Fimreite and Karstat 1971).

Survey Flight Timing

The censusing work conducted in 1995 was successful in obtaining an indication of population size, distribution and nest site use of bald eagles and ospreys around the Williston Reservoir. However, the surveys were not definitive in determining the timing of egg laying or the productivity of these populations. Funding and staff resources permitted only 2 flights in the 1995 breeding season: one to determine clutch sizes and the other to determine fledgling success. Given that bald eagle and osprey breeding chronologies do not coincide, conducting clutch and fledglings surveys for both species together provided incomplete data for many of the nests. Activity flights should be conducted immediately after the last clutch has been started. Productivity flights should be conducted just before young begin to leave the nest (Fraser *et al.* 1983). It is important to

schedule flights on dates when these events most often take place; failure to do so can result in errors presented in Table 16.

Table 16. Sources of error in the sampling of raptor nest sites (from Fraser *et al.* 1983)

Occupancy survey	Activity survey	Productivity survey
failure to find adults near the occupied nest	flights scheduled before eggs were laid or after a nest failure	birds are still incubating or brooding young
eagles occupying a previously undiscovered nest	birds were active at a new nest	inability to see young in nest
miss counting young at nest	newly hatched young were not observed at nest	flights took place after young had fledged or nests had failed

Examples of these errors are evident in the data that we collected from the occupied nests of both bald eagles and ospreys. Some of the juvenile bald eagles had already fledged by the time the 3rd flight was conducted resulting in our inability to determine the fledging success of 14 (37%) of these nest sites. In contrast, many of the osprey young were not far enough advanced by this time to accurately estimate how many of the young would fledge. This was the case for 39 (43%) of the occupied osprey nests. As a result, the direction of the bias (over or underestimating productivity) for ospreys is unclear.

RECOMMENDATIONS

Further Raptor Inventory

Based on the fact that the number of surveys and survey timing was found to be ineffective in determining productivity, we recommend that more surveys be conducted within a given breeding season. It is important to match the nesting chronologies of all target species with the timing of aerial surveys (Steenhof 1987). This will likely mean that separate clutch size and productivity (fledgling) flights will be required for both ospreys and bald eagles. In addition, because Williston Reservoir is such a large area to inventory, survey segments may need to be staggered to compensate for intra-regional differences in nesting chronology (Todd 1979 as cited in Steenhof 1987).

Better estimates of productivity will benefit the management of these species in numerous ways: 1) they will provide a baseline upon which to monitor long-term population trends, 2) they will provide a baseline upon which to monitor/compare productivity in artificially enhanced areas, 3) they will provide an indication of the general health of the bald eagle and osprey populations and their prey bases, and 4) they will provide more accurate productivity data used to direct enhancement and protection activities should they be

necessary. This is especially true for osprey nesting enhancement. Knowing the differential reproductive success of different sizes of colonies can help in the creation of additional osprey nesting sites. Examining the nearest neighbour effects can also influence the placement of nesting structures in enhanced osprey nesting habitat. It is also essential that productivity flights continue well into the future so that population trends can be monitored over time.

Expansion of Survey Area

Creation of the Williston Reservoir has dramatically changed the extent and nature of the riparian habitat in the area, with a substantial change from riverine to lake habitat. This flooding likely decreased the availability of suitable bald eagle nesting sites due to the inundation of the valley bottom riparian habitat (areas of extensive cottonwood flats). Conversely, the flooding of the 3 major rivers to form the Reservoir in conjunction with the lack of logging prior to flooding, has led to the creation of extensive areas of standing dead trees that have remained above the water level of the Reservoir. These trees now provide ideal nesting habitat for ospreys.

Although a true impact assessment is impossible, expanding the survey area to include the major rivers that flow into the Williston Reservoir would provide some insight to what bald eagle and osprey densities and productivity may have been had the reservoir area not been flooded. A study of this nature should include unaltered riverine systems in the northern part of the province that are not linked to the Peace system. The construction of the WAC Bennett Dam has altered fish and waterfowl communities in the upper Peace River system, thus, the rivers flowing into the Williston Reservoir may also have an altered prey base.

LITERATURE CITED

Anderson, R.J. 1985. Bald eagle and forest management. For. Chron 61:189-192

Andrew, J.M. and J.A. Mosher. 1982. Bald eagle nest selection and nesting habitat in Maryland. J. Wildl. Manage. 46:383-390.

Anthony, R.G. and F.B. Issacs. 1989. Characteristics of bald eagle nest sites in Oregon. J. Wildl. Manage. 53:148-159.

Anthony, R.G., R.W. Frenzel, F.B. Issacs, and M.G. Garrett. 1994. Probable causes of nesting failures in Oregon's bald eagle population. Wildl. Soc. Bull. 22:576-582.

Anthony, R.G., R.L. Knight, G.T. Allen, B.R. McClelland and J.I. Hodges. 1982. Habitat use by nesting and roosting bald eagle in the Pacific Northwest. Trans. North Am. Wildl, and Nat. Resour. Conf. 47:332-342.

Austin-Smith, P.J. and G.E. Dickie 1986. Nesting success and productivity of Bald eagles *(Haliaeetus leucocephalus)* in Nova Scotia. Technical Note #43, Nova Scotia Department of Lands and Forests, Kenaville. 2 pp.

Bangs et. al. 1982. Ecology of nesting bald eagles on the Kenai National Wildlife Refuge, Alaska. Pages 47-54 *in* W.N. Ladd and P.F. Schempf eds. Proceedings of the Raptor Management and Biology symposium. Alaska Regional Office, USFS, Anchorage, AK. USA

B.C. Ministry of Environment. 1989. Results from bald eagle nest tree measurements in the Fraser Valley, B.C. Unpublished data.

BC Hydro. 1987. Peace Canyon Dam and Generating Station. B.C. Hydro Fact Sheet. 6pp.

BC Hydro. 1988. Williston Reservoir Raising: Environmental Overview. B.C. Hydro, Environmental Services, System Operations and Maintenance Division. Report No. ES-118. 83 pp.

BC Hydro. 1991. W.A.C. Bennettt Dam and G.M. Shrum Generating Station. B.C. Hydro Fact Sheet. 6pp.

Bernatowicz, J.A. P.P. Schempf, and T. D. Bowman. 1996. Bald eagle productivity in South-central Alaska in 1989 and 1990 after the Exxon Valdez Oil Spill. Amer. Fish. Soc. Symp. 18:785-797.

Bider, J.R. and D.M. Bird. 1983. Distribution and density of osprey populations in the Great Whale Region of Quebec. Pages 223-230 , *in* D.M. Bird, (ed). Biology and Management of Bald Eagles and Ospreys, Ste. Anne de Bellevue, Quebec: Harpell Press.

Blood, D.A. 1989. Conservation plan for bald eagle nest trees in the Nanaimo area. Report prepared for B.C. Mininstry of Environment, Vancouver Island Region, Nanaimo, B.C. 33 pp.

Blood, D.A. and G.G. Anweiler (1990). Nesting chronology and success of bald eagles in southwest Yukon. Northwestern Nat. 71:9-11.

Blood, D.A. and G.G Anweiler (unpublished). Bald eagle nests per km of shoreline, interior British Columbia and southern Yukon. 7 pp.

Booth, B.P. and A.C.M. Farr 1993. Bald eagles in the Lower Mainland-Fraser Valley Region of B.C.: First steps towards and Conservation strategy. Report submitted to Habitat Conservation Fund, Vulnerable Species Inventory and Habitat Protection. 46 pp.

Buehler, D. A.., J.D. Fraser, J.K.D. Seeger, G.D. Therres, M.A. Byrd. 1991. Survival rates and population dynamics of bald eagles on Chesapeake Bay. J. Wildl. Manage. 55:608-613.

Bunnell, F.L, B. P. Booth, and A.C.M. Farr 1990. Bald Eagles and Forestry. B.C. Ministry of Environment-Wildlife tree committee, Wildlife Habitat Canada, 8 page pamphlet.

Corr, P.O. 1974. Bald eagle *(Haliaeetus leucocephalus alascanus)* nesting related to forestry in southeastern Alaska, M.S. Thesis, University of Alaska, College, Alaska. 144pp.

Dzus, E.H. and J.M. Gerrard. 1993. Factors influencing bald eagle densities in northcentral Saskatchewan. J. Wildl. Manage. 57:771-778.

Dzus, E.H. and J.M. Gerrard. 1989. Interlake variations of bald eagle, *Haliaeetus leucocephalus,* populations in northcentral Saskatchewan. Canad. Field. Nat. 103:29-33.

Eisler, R. 1987. Mercury hazards to fish, wildlife and invertebrates: A synoptic review. Biological Report 85(1.10) April 1987. Contaminant hazard reviews report No. 10. U.S. Fish and Wildlife Service. U.S. Department of the Interior. 90 pp.

Elliott, J.E. 1995. Environmental contaminants in bald eagles on the coast of British Columbia: exposure and biological effects. Ph.D. Thesis. University of B.C. 153 pp.

Farr, A.C.M. 1988. Managing habitat for bald eagles in the Fraser Valley of British Columbia: 1987-1988 Observations. Report to World Wildlife Fund (Canada), Toronto, Ontario. 27 pp.

Fimreite, N. and L. Karstat. 1971. Effects of dietary methyl mercury on red-tailed hawks. J. Wildl. Manage. 35:293-300.

Flemming, S.P., R.P. Bancroft and N.R. Seymour. 1991. Enhanced fledgling success by colonially nesting ospreys in Nova Scotia coastal habitat. Wilson Bull. 103(4): 664-668.

Flook, D.R. and L.S. Forbes. 1983. Ospreys and water management at Creston. Pages 281-286 *in* D.M. Bird, (ed). Biology and Management of Bald Eagles and Ospreys, Ste. Anne de Bellevue, Quebec: Harpell Press.

Forbes, L.S. and G.W. Kaiser. 1984. Observations of breeding bald eagles in southeastern British Columbia. Murrelet 65:22-25

Fraser J.D. 1985. The impact of human activities on bald eagle populations-a review. Pages 68-84 *in* J.M. Gerrard, T.N. Ingram, eds. The Bald Eagle in Canada. White Horse Plains Publishers, Headingley, Manitoba.

Fraser J.D., L.D. Frenzel, and J.E. Mathisen. 1985. The impact of human activities of breeding bald eagle in north-central Minnesota. J. Wildl. Manage. 49:585-592.

Fraser J.D., L.D. Frenzel, J.E. Mathisen, F. Martin, M.E. Shough. 1983. Scheduling bald eagle reproduction surveys. Wildl. Soc. Bull. 11:13-16.

Gerrard, J.M., P. Gerrard, W.J. Maher, and D.W.A. Whitfield. 1975. Factors influencing nest site selection in northern Saskatchewan and Manitoba. Blue Jay 33:169-176.

Gerrard, J.M., P.N. Gerrard, G.R. Bortolotti, and D.W.A. Whitfield. 1983. A 14 year study of bald eagle reproduction on Besard Lake, Saskatchewan. Pages 47-57 *in* D.M. Bird, (ed). Biology and Management of Bald Eagles and Ospreys, Ste. Anne de Bellevue, Quebec: Harpell Press.

Gerrard, P.N. and J.M. Gerrard and G.R. Bortolotti. 1985. The impact of road development and tourist access on a bale eagle population at Besard Lake, Saskatchewan. Pages 160-165 *in* J.M. Gerrard, T.N. Ingram, eds. The Bald Eagle in Canada. White Horse Plains Publishers, Headingley, Manitoba.

Green, N. 1985. The Bald Eagle. Audubon Wildlife Report. 508-531.

Greene, E. 1987. Individuals in an Osprey colony discriminate between high and low quality information. Nature 329:239-241

Grier, J.W., FJ. Gramlich, J.Mattsson, J.E. Mathisen, J.V. Kussman, J.B. Elder, and N.F. Green. 1983. The bald eagle in the northern United States. Bird Conserv. 1:41-66.

Grover, K.E. 1984. Nesting distribution and reproductive success of ospreys along the upper Missouri River, Montana. Wilson Bull. 96:496-498.

Grubb, T.G. 1980. An evaluation of bald eagle nesting in western Washington. Pages 87-104 *in* R.L. Knight, G.T. Allen, M.V. Stalmaster, C.W. Servheen, eds. Proc. Washington Bald Eagle Symp, Seattle.

Hagan, J.M. 1984. A North Carolina osprey population: social group or breeding aggregation. Pages 43-60 in M.A. Westall (ed), Proceedings of the Southeastern US and Carribean Osprey Symposium. Sanibel, FL.

Hagan, J.M. 1986. Temporal pattens in pre-fledging survival and brood reduction in an osprey colony. Condor 88:200-205.

Hagan, J.M. and J.R. Walters. 1990. Foraging behaviour, reproductive success, and colonial nesting in ospreys. The Auk 107: 506-521.

Hansen, A.J. and J.L. Hodges. 1985. High rates of non-breeding adult bald eagles in southeastern Alaska. J. Wildl. Manage. 49:454-458.

Hansen, A.J. 1987. Regulation of bald eagle reproductive rates in southeast Alaska. Ecology 68:1387-1392.

Heinz, G.H. 1979. Methylmercury: reproductive and behavioural effects on three generations of mallard ducks. J. Wildl. Manage. 43:394-401.

Henny, C.J. 1983 Distribution and abundance of nesting ospreys in the United States. Pages 175-186 *in* D.M. Bird, (ed). Biology and Management of Bald Eagles and Ospreys, Ste. Anne de Bellevue, Quebec: Harpell Press.

Henny, C.J. and A.P. Noltmeier. 1975. Osprey nesting populations in the coalstal Carolinas. Am. Birds 29:1073-1079.

Henny, C.J. and H.M. Wight. 1969. An endangered osprey population: estimates of mortality and production. Auk. 86:188-198.

Henny, C.J., M.A. Byrd, J.A. Jacobs, P.D. McLain, M.R. Todd, B.F. Halla. 1977. Mid-Atlantic coast osprey population: present numbers, productivity, pollutant contamination, and status. J. Wildl. Manage. 41:254-265.

Hickey, J.J. and D.W. Anderson. 1968. Chlorinated hydrocarbons and egshell changes in ratorial birds and fish eating birds. Science 162:271-273.

Hodges J.L, J.G. King, and R. Davies. 1984. Bald eagle breeding population survey of coastal British Columbia. J. Wildl. Manage.. 48:993-998.

Hodges. J.I and F. C. Robards. 1982. Observations of 3850 Bald Eagle nests in southeast Alaska. Pages 37-46 *in* W. N. Ladd and P. F. Schempf. editors. Proceedings of the Raptor Management and Biology Symposium. Alaska Regional Office, United States Fish and Wildlife Service, Anchorage, Alaska. USA.

Hughes, J. 1982. The osprey in southeast Alaska. Pages 197-204 *in* W.N. Ladd and P.F. Schempf eds. Proceedings of the Raptor Management and Biology symposium. Alaska Regional Office, USFS, Anchorage, AK. USA

Issacs, F.B. and R.G. Anthony. 1996. Bald eagle nest locations and history of use in Oregon 1971 through 1996. Ore. Coop. Wildl. Reservoirs. Unit, Ore. State Univ., Corvallis. 18 pp, 5 tables, 1 figure, 1 appendix.

Issacs, F.B., R.G. Anthony, and R.J. Anderson. 1983. Distribution and productivity of nesting bald eagles in Oregon, 1978-1982. The Murrelet 64:33-38.

Judge, D.S. 1983. Productivity of ospreys in the Gulf of California. Will. Bull. 95:243-255.

Kralovec, M.L., R.L. Knight, G.R. Craig, and R.G. McLean. 1992. Nesting productivity, food habitats and nest sites of bald eagles in Colorado and southeastern Wyoming. SW Naturalist 37:356-361.

Kushlan, J.A. and O.L. Bass. 1983. Decreases in the southern Florida osprey population, a possible result of food stress. Pages 187-200 *in* D.M. Bird, (ed). Biology and Management of Bald Eagles and Ospreys, Ste. Anne de Bellevue, Quebec: Harpell Press.

Levenson, H. and J.R. Koplin. 1984. Effects of human activity on productivity of nesting ospreys. J. Wildl. Manage. 48:1374-1377.

Little, B. 1994. Osprey enhancement project: Carpenter Reservoir. B.C. Hydro - Environmental Affairs Division, Land Resources Dept., Burnaby, B.C. Report No. EA-94-2. 12 pp. + appendices.

Lueke-Joyce, T. 1988. Bald Eagle Nest Location Report: Tree Farm License 6 (Quatsino) and Tree Farm License 25, Block 4 (Port McNeill). Report to Western Forest Products Ltd. 33 Pages.

MacCarter, D.L. and D.S. MacCarter. 1979. Ten-year status of ospreys at Flathead Lake Montana. The Murrelet 60:42-49.

Mathisen, J. E. 1983. Nest site selection by bald eagles on the Chippewa National Forest. Pages 95-100 *in* R.L. Knight, G.T. Allen, M.V. Stalmaster, C.W. Servheen, eds. Proc. Washington Bald Eagle Symp, Seattle.

Mathisen, J.E. 1968. Effects of human disturbance on nesting of bald eagles. J. Wildl. Manage. 32:1-5.

Mattson J.P. and A.H. Grewe. 1976. Bald eagle nesting in the Superior National Forest. U.S. Forest Service Note NC-198.

McAllister, K.R., T.E. Owens, L. Leschner, and E. Cummins. 1986. Distribution and productivity of nesting bald eagles in Washington, 1981-1985. The Murrelet 67:45-50.

McEwan, L.C. and D.H. Hirth. 1979. Southern bald eagle productivity and nest site selection. J. Wildl. Manage. 43:585-594.

McGarigal, K., R.G. Anthony, and F.B. Issacs. 1991. Interactions of humans and bald eagles on the Columbia River Estuary. Wildl. Mono. No. 115.

McPhail, J.D. and R.Carveth. 1993. Field key to the freshwater fishes of British Columbia. Univeristy of British Columbia, Vancouver, BC. 239 pp.

Nash, C, M. Pruett-Jones, and G.T. Allen. 1980. The San Juan Islands bald eagle nesting survey. Pages 105-115 *in* R.L. Knight, G.T. Allen, M.V. Stalmaster, C.W. Servheen, eds. Proc. Washington Bald Eagle Symp, Seattle.

Newton, I. 1979. Population Ecology of Raptors. Buteo Books. Vermillion, South Dakota.

Ogden, J.C. 1975. Effects of bals eagle territoriality on nesting ospreys. Wilson Bull. 87: 496-505.

Oneil, E. 1988. Bald eagle nesting relative to forestry operations on Macmillan Bloedel Forest Lands. B.S.F. Thesis. U.B.C. Faculty of Forestry.

Poole, A. 1982. Brood reduction in temperate and subtropical ospreys. Oecologia 53: 111-119.

Poole, A. 1989. Ospreys, a natural and unnatural history. Cambridge, Cambridge Univ. Press.

Postupalsky, S. 1974. Raptor reproductive success: some problems with methods, criteria and terminology Pages 21-31 *in* F.N. Hamerstrom, Jr. B. E. Harrell, and R.R. Ohlendorff (eds) Managemant of raptors. Proc. conference on rpator conservation techniques, Raptor. Res. Rep. 2, Paptor Res. Found. Inc., Vermillion, S.D.

Rhodes, L. I. 1972. Success of osprey nest structures at Martin National Wildlife Refuge. J. Wildl. Manage. 36: 1296-1299.

RIC (Resource Inventory Committee). 1997. Standard Inventory Methodologies for Components of British Columbia's Biodiversity: Raptors. Version 1.1. RIC, Ministry Of Environment, Lands & Parks, Victoria, BC. 56 pp.

Ritchie, R.J. 1982. Investigations of bald eagles, Tanana River, Alaska, 1977-1980. Pages 55-67 *in* W. N. Ladd and P. F. Schempf. editors. Proceedings of the Raptor Management and Biology Symposium. Alaska Regional Office, United States Fish and Wildlife Service, Anchorage, Alaska. USA.

Roberts, H.B. and G.S. Lind. 1977. Status of the American Osprey in Oregon. Transactions of the N. Am. Osprey Research Conf. College of William and Mary, Williamsburg, Virginia. 10-12 Feb. 1972. J.C. Ogden ed., USDI Trans, and Proc. Series Two-1977. pp 215-222.

Saurola, R, 1983. Population dynamics of the osprey in Finland during 1971-80. Pages 201-206 *in* D.M. Bird, (ed). Biology and Management of Bald Eagles and Ospreys, Ste. Anne de Bellevue, Quebec: Harpell Press.

Seymour, N. R. and R.P. Bancroft. 1983. The status and use of two habitats by ospreys in Northeastern Nova Scotia. Pages 275-280 *in* D.M. Bird, (ed). Biology and Management of Bald Eagles and Ospreys, Ste. Anne de Bellevue, Quebec: Harpell Press.

Siddle, C. 1990. The bald eagle in the Peach River region of B.C. Report prepared for D. Blood and Associates, Ltd. Nanaimo, B.C. 15 pp.

Smith, C.F. and C. Ricardi. 1983. Ospreys and bald eagles in New Hampshire: Status, habitat and nest site comparisons. Pages 149-156 *in* D.M. Bird, (ed). Biology and Management of Bald Eagles and Ospreys, Ste. Anne de Bellevue, Quebec: Harpell Press.

Sprunt, A., W.B. Robertson, S. Potuplasky, R.H. Hensel, C.E. Knoder, FJ. Ligas. 1973. Comparative productivity of six bald eagle populations. Trans. 38th N.A. Wildl. & Natur. Resour. Conf. pp. 96-105.

Stalmaster, M.V. 1987. The Bald Eagle. Universe Books: New York. 227pp.

Steeger, C. and R.C. Ydenberg. 1993. Clutch size and initiation date of ospreys: natural patterns and the effect of a natural delay. Can J. Zool. 71:2141-2146.

Steeger, C., H. Esselink, and R.C. Ydenberg. 1992. Comparative feeding ecology and reproductive performance of ospreys in different habitats of southeastern British Columbia. Can J. Zool. 70:470-475.

Steenhof, K. 1987 Assessing raptor reproductive success and productivity. Pages 157-170 *in* Pendelton, B.A., B.A. Millsap, K.W. Cline and D.M. Bird (eds). Raptor management techniques manual, Institute of wildife research, National Wildlife Federation, Scientific and Tech. Series No. 10.

Steidl, R.J., C.R. Griffin, L.J. Niles. 1991. Contaminant levels of osprey eggs and prey reflect regional differences in reproductive success. J. Wildl. Manage. 55:601-608.

Stocek, R.F. and P.A. Pearce. 1983. Distribution and reproductive success of ospreys in New Brunswick, 1974-80. Pages215-222 *in* D.M. Bird, (ed). Biology and Management of Bald Eagles and Ospreys, Ste. Anne de Bellevue, Quebec: Harpell Press.

Swenson, J.E., K.L. Alt, and R.L. Eng. 1985. Ecology of bald eagles in the Greater Yellowstone Ecosystem. Wildl. Mono. 95:1-46.

Therres, G.D. M.A. Byrd, and D.S. Bradshaw. 1993. Effects of development on nesting bald eagles: Case studies from Chesapeake Bay. Trans. 58th N.A. Wildl. & Natur. Resour. Conf. pp. 62-69.

USDA Forest Service 1988. Bald eagle/osprey nesting success in the National Forests of the eastern region. 26th annual report. USDA Forest Service, Eastern Region, Milwaukee, WI.

Van Daele, L. J. and H.A. Van Daele. 1982. Factors affecting the productivity of ospreys nesting in west-central Idaho. Condor 84:292-299.

Vermeer, K. and K.H. Morgan. 1989. Nesting population, nest sites, and prey remains of bald eagles in the Barkley Sound, B.C. Northwest Nat. 70:21-26.

Vermeer, K., K.H. Morgan, R.W. Butler and G.E. Smith. 1987. Population, nesting and food of bald eagle in the Gulf Islands. Pages 123-130 *in* K. Vermeer and R.W. Butler, eds. The ecology and status of marine and shoreline birds in the Strait of Georgia, British Columbia, Sidney, B.C.

Washington State Dept of Fish and Wildlife (unpublished data). Bald eagle nest success and productivity rates, Pacific Recovery Region, 1986-1994

Washington State Dept of Fish and Wildlife (unpublished data). Breeding survey data for bald eagles in Washington State, 1994.

Watson, T. 1992. Evaluation of mercury concentration in selected environmental receptors in the Williston Reservoir and Peace River areas of B.C., Triton Environmental Resources, Richmond, B.C.

Wetmore, S.P. and D.I. Gillespie. 1976. Osprey and bald eagle populations in Labrador and Quebec. Can. Field Nat. 90:330-337.

Wiemeyer, S.N., T.G. Lamont, C.M. Bunck, C.R. Sindelar, FJ. Gramlich, J.D. Fraser, and M.A. Byrd. 1984. Organochlorine pestidicide, polychlorobiphenyl, and mercury residues in bald eagle eggs-1976-1979-and their relationships ot shell thinning and reproduction. Arch. Environ. Contam. Toxicol. 131:529-549.

Wood, R.B. and M. W. Collopy. 1993. Effects of egg removal on bald eagle productivity in northern Florida. J. Wildl. Manage. 57:1-9.

Zemlak, R.J., M.D. Wood, and F.B. Corbould. 1995. Williston and Dinosaur Reservoirs raptor survey 1995: Survey 1, Raptor nest locations. Peace/Williston Fish and Wildlife Compensation Program Report No. 43, Prince George, B.C. 8 pp. plus appendices.